



# Accelerator Physics Center: The 1<sup>st</sup> Year

Vladimir Shiltsev / APC  
FRA Physics Visiting Committee  
April 25/26 2008

---



# Accelerator Physics Center





- Coordinate and conduct accelerator R&D aimed at next-generation and beyond accelerator facilities
- Provide accelerator physics support for existing operational programs and the evolution thereof
- Train accelerator scientists and engineers
- Provide leadership and coordination in establishing the necessary facilities for a broad range of accelerator R&D that can be accessed by both Fermilab and the world HEP community





## APC General Meeting/Mini-Retreat, March 11 2008

- 43 staff (including 26 Sci/Phys, 3 PF, 6 Eng, 3 postdocs)
- 3 joint appointments, 8 PhD students
- 25 associates(part-timers) from AD/TD/PPD/CD divisions



# APC Organization



## ACCELERATOR PHYSICS CENTER

V.Shiltsev, Director  
M.Church, Deputy Director  
M.Bruce, Admin Associate  
(A.Nestander), Budget Mgr.

### ILC Beam Physics Department

(N.Solyak), Head

ILC Modeling Group  
M.Church (GL)

### LHC Accelerator Group

T.Sen (GL)

### Theory/Simulation Group

Yu.Alexahin (GL)

### Energy Deposition Group

N.Mokhov (GL)

### Exper. AAR&D Group

P.Piot (GL)

### (CD/CPA Group)

(P.Spenzouris, GL)

### Muon Accelerator R&D Department

S.Geer, Head

### MCTF Experiment Group

A.Jansson (GL)

### NFMCC Group

A.Bross (GL)

### HINS Department

R.Webber, Head

### US PAS Office

S.Winchester (GL)

W.Barletta, Director (GS)

### Accel.Education Dept.

(V.Lebedev), Head

### Accel.PhD Program

(A.Tollestrup, Chair)

### Peoples Fellowship

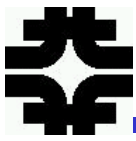
(M.Church, Comm.Chair)

### Lee Teng Internship

(E.Prebys, Comm.Chair)

### Accel.Summer Students

(A.Shemyakin, Prgm.Ldr.)



- Objectives:
  - Demonstrate high power RF distribution and long-pulse operation of multiple cavities powered from a single klystron
  - Demonstrate 325 MHz high power vector modulators for amplitude and phase control of multiple cavities
  - Measure axially-symmetric beam performance with room-temperature crossbar spoke resonator cavities and SC solenoid focusing in the front-end Linac
  - Demonstrate high intensity beam acceleration at 10 MeV and beyond using superconducting spoke resonator RF structures
  - Demonstrate high-speed (nsec) beam chopping at 2.5 MeV
  - Demonstrate performance of this Linac design concept and measure the resulting beam quality to 60 MeV

**This all adds up to building a one-of-a-kind SC 60 MeV H- linac**

- Recent progress and plans:
  - Successful test of HP vector modulator
  - 13MV/m achieved in the first SC spoke resonator
  - 2.5MeV RFQ to be delivered this Summer
  - 2.5MeV beam out of RFQ by the end of CY

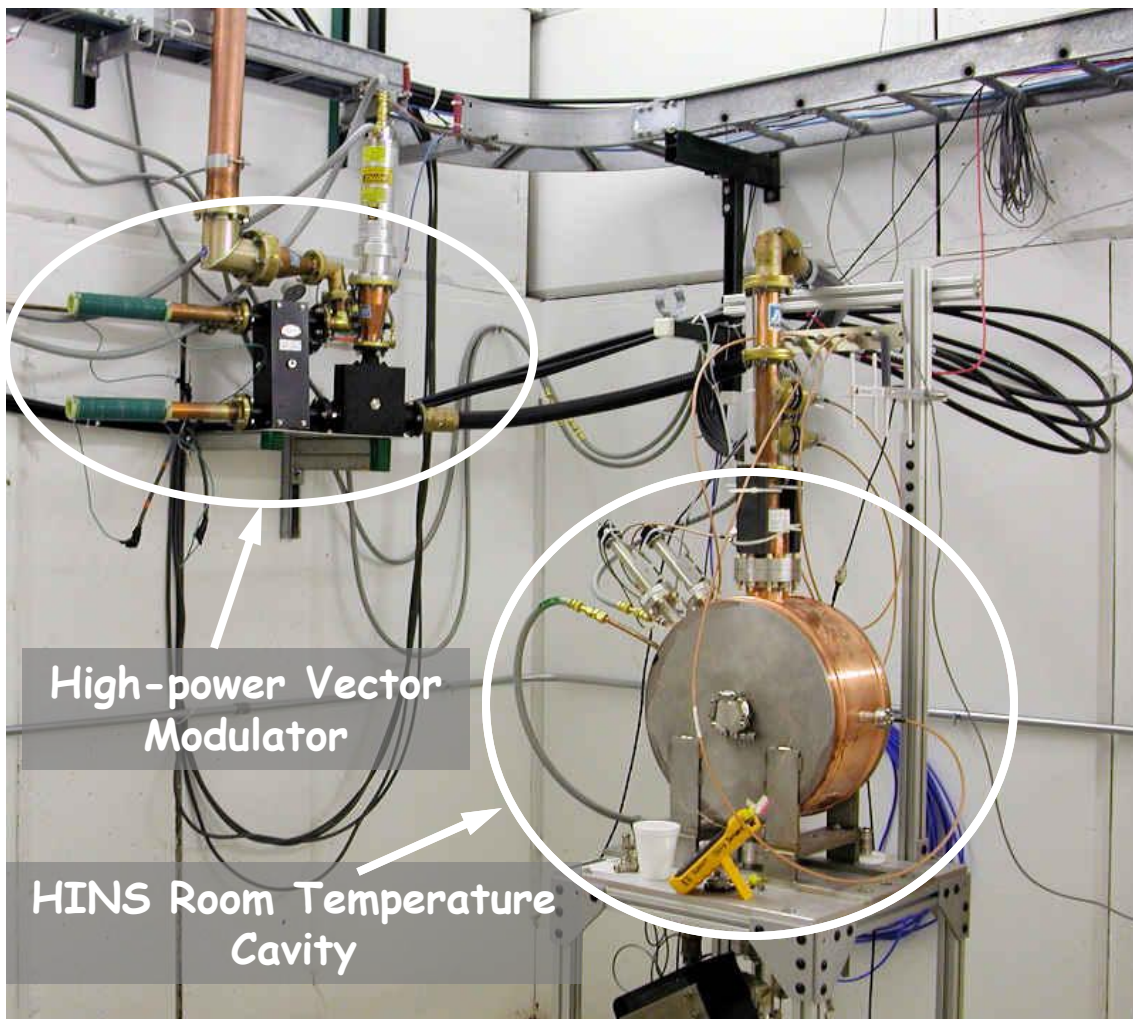




# HINS RT Cavity and Vector Modulator Operating in Cavity Test Cave @ MDB

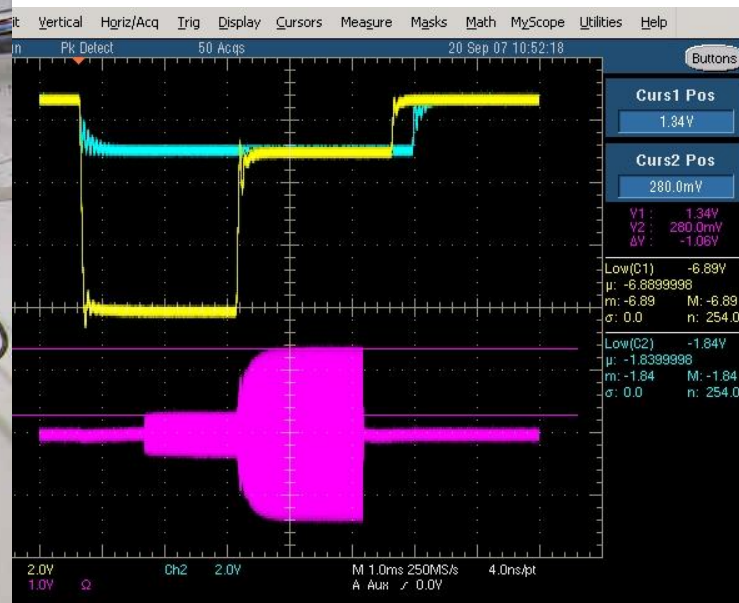


D.Wildman, R.Madrak



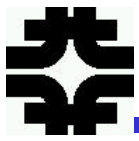
High-power Vector  
Modulator

HINS Room Temperature  
Cavity



13 dB Amplitude Control with  
Vector Modulator for 6 kW  
3.5 msec RF Pulse

Red trace is cavity RF  
amplitude; blue and yellow are  
vector modulator bias currents



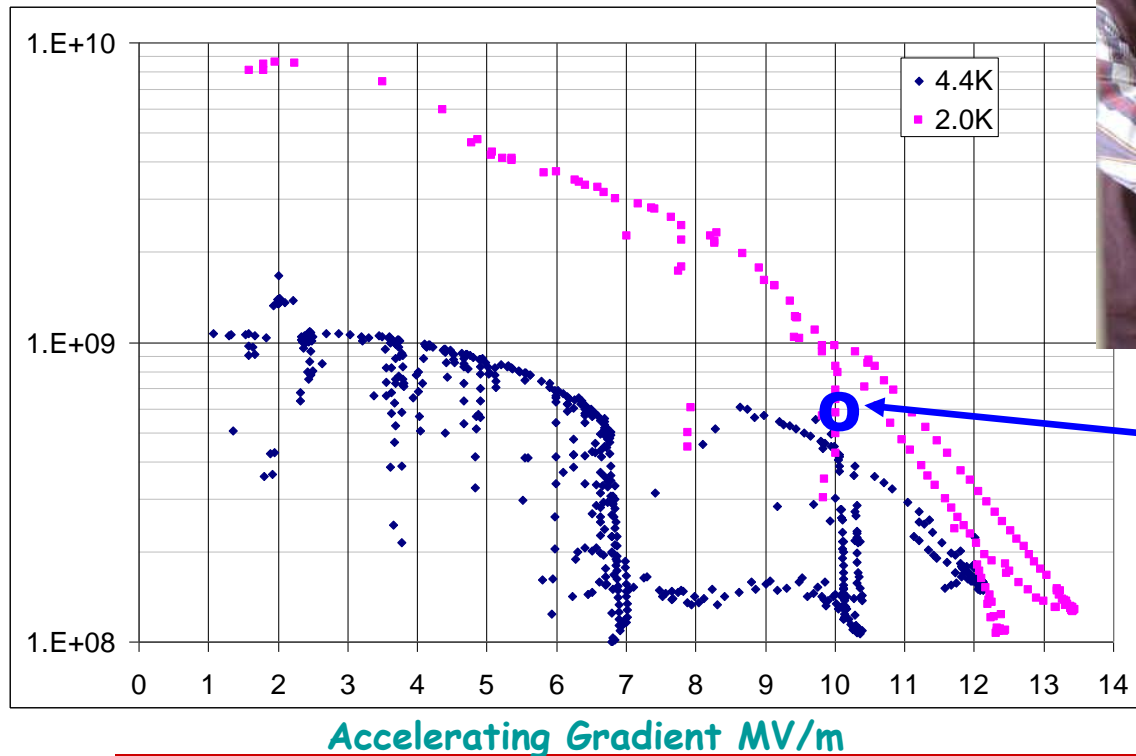
# HINS SC Spoke Cavity at VTS



SSR1-01 Vertical Test  
March 12, 2008  
Design 10 MV/m  
Achieved 13 MV/m

T.Khabibulin, R.Wagner, J.Ozelis

Q vs. E



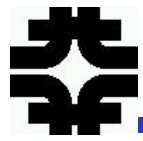
Dressed Cavity  
Operating Goal @ 4K





- Muon Collider Feasibility Study to be credible lepton collider option by 2013:
  1. Coherent MC design at the level of ZDR
  1. MICE experiment (successful) results
  1. Key RF questions answered
  2. Prospects of HTS magnets understood
  3. Muon acceleration techniques explored
- Also by 2012-13: Neutrino Factory RDR
  - ✓ Part of international team

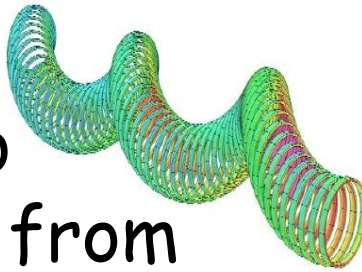
- see talk by A.Bross



# Muon Research Program

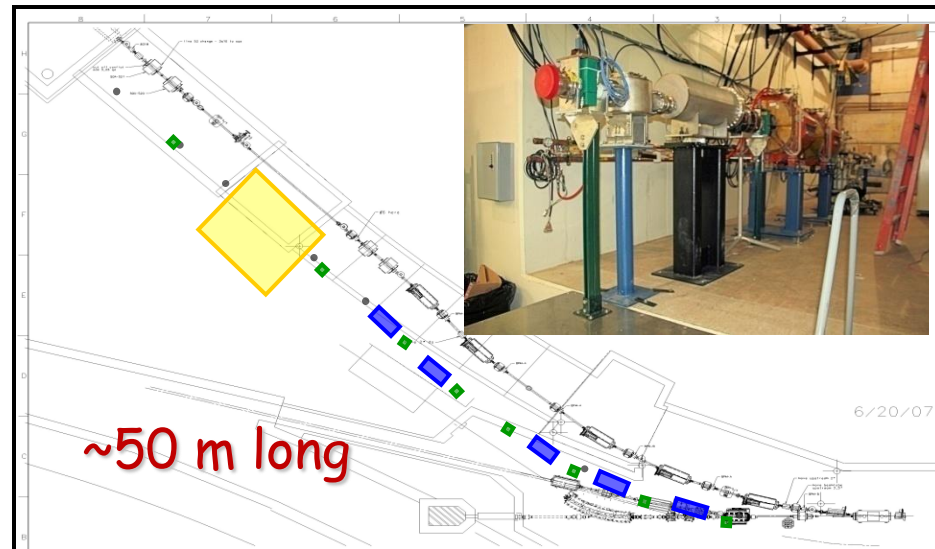


- Test of components for MICE (RF, coils)
- Build 6D cooling components (HCC)
- Build a beamline to bring 400 MeV H<sup>-</sup> from Linac :



- HCC uses high pressure H<sub>2</sub> cavities
- Test with beam needed to understand if HPRF cavities are useful.

- see talk by A. Bross





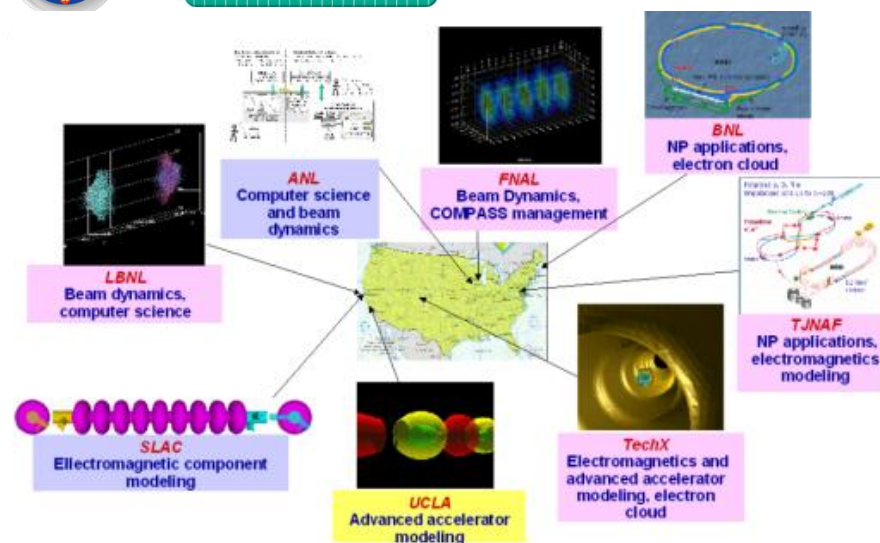
P.Spentzouris

- Development of HPC accelerator modeling tools and applications
  - Multi-particle dynamics
  - Scalable and efficient solvers
  - Management of ComPASS collaboration
- Development and support of CHEF
  - general framework applicable to problems relevant to future machine design.
  - Application to ILC, Pr-X

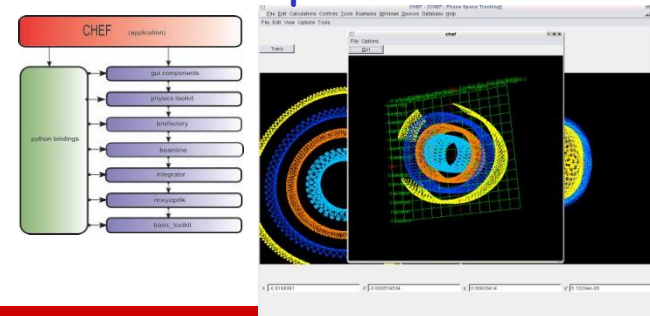
## The SciDAC ComPASS collaboration



<https://compass.fnl.gov/>

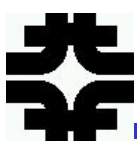


## Collaborative Hierarchical Expandable Framework



F.Ostiguy



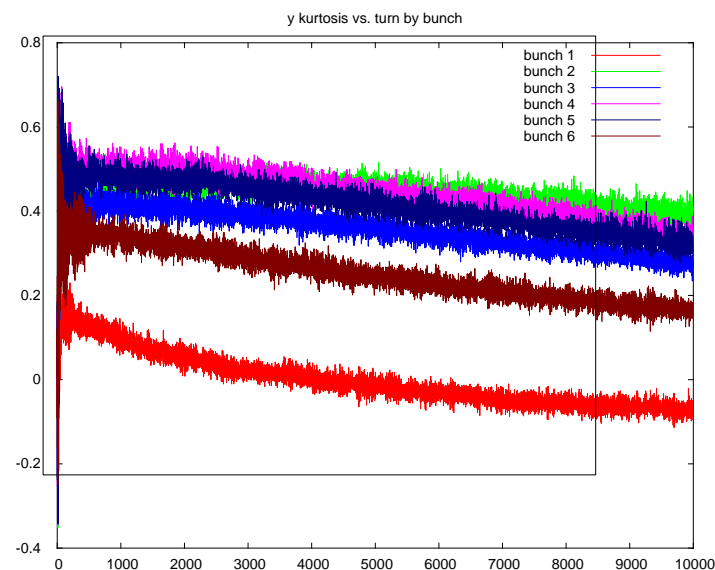
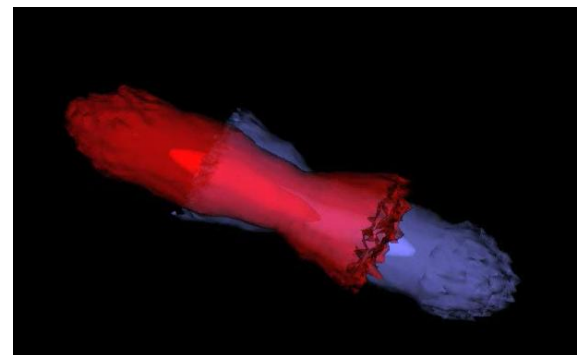


# Accelerator Modeling: Applications



E.Stern, A.Valishev

- Utilize mature 3D space-charge capabilities
  - Recycler (Project-X), Booster
- Conclude multi-bunch Tevatron simulations
  - Beam-beam 3D & impedance
- Begin MI e-cloud simulation
  - @ FNAL & within ComPASS
- Continue development of CHEF generic linac applications
- Explore possibilities for using CHEF in other APC activities
  - Ionization cooling, LHC

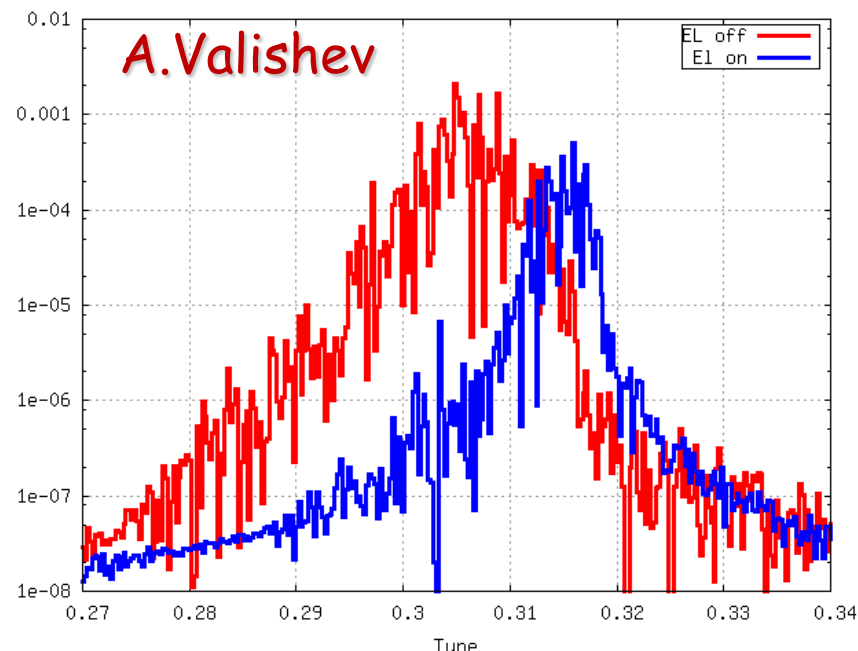
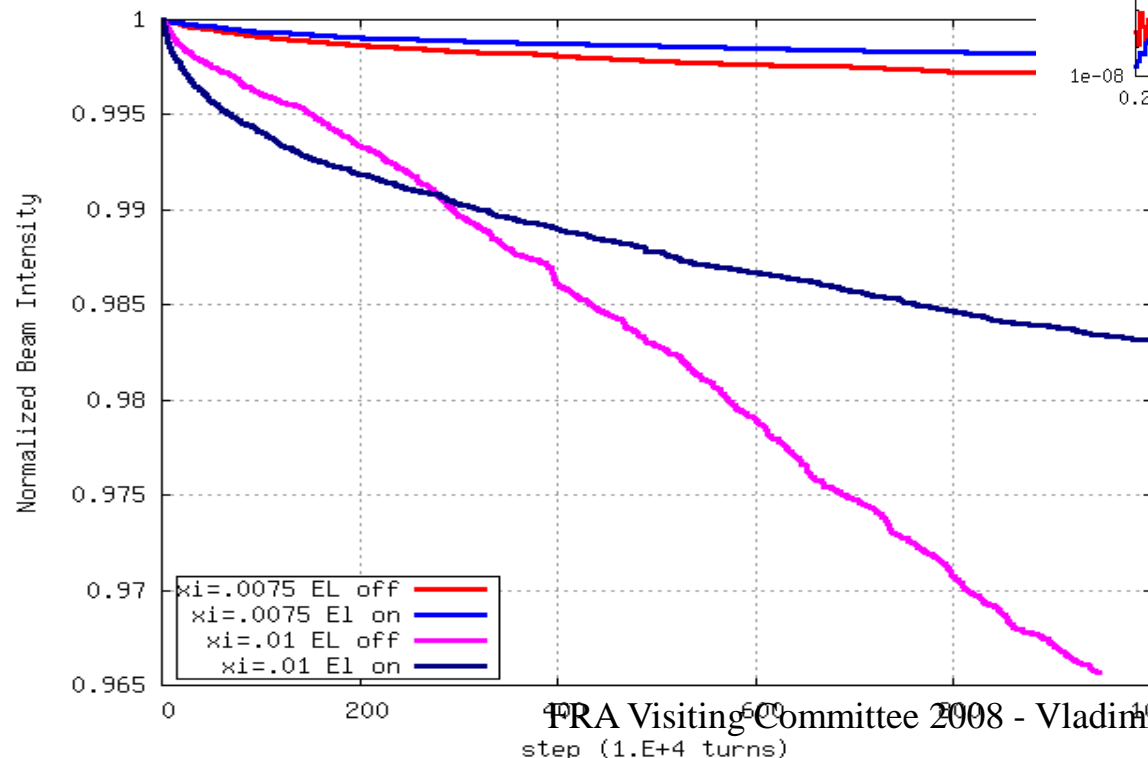




# Beam-Beam Simulations: LHC e-Lenses



- Simulation with LIFETRAC - weak-strong macroparticle code.  $1E4$  particles  $\times$   $1E7$  turns
- 6D maps and beams separations from MADX. 1<sup>st</sup> and 2<sup>nd</sup> order chromaticity, diffusion
- 1 Gaussian electron lens  $\sim 102\text{m}$  from IP1 with e-beam size matched to proton beam, acting as head-on tune spread compensator



- At  $\xi = 0.0075$  (doubled beam intensity) non-luminous losses are reduced by  $\frac{1}{2}$
- At  $\xi = 0.01$  (triple beam intensity) life time is improved by a factor of 4!

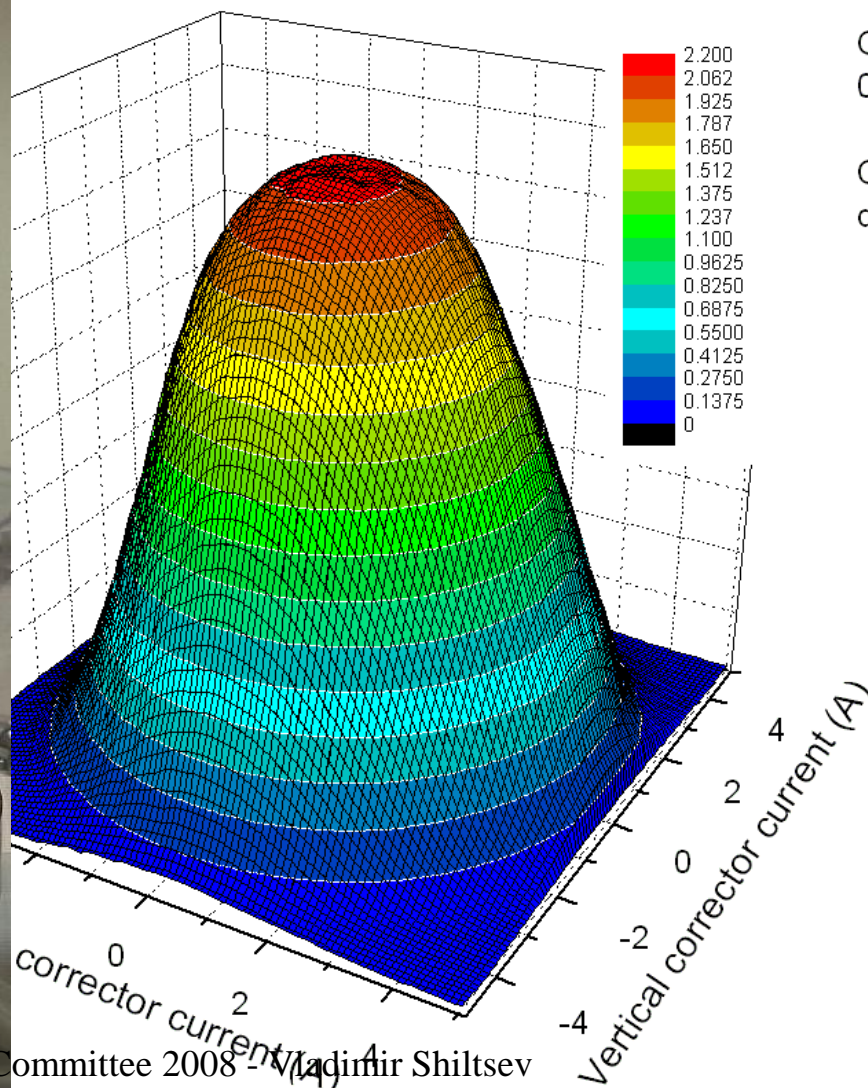


# Gaussian Gun for LHC electron lenses



V.Kamerdzhev

## MEASURED ELECTRON BEAM PROFILE



Gaussian electron  
0.4" cathode

Current density  
distribution

$$U_{\text{cath}} = -5\text{kV}$$

$$U_{\text{ce}} = -5\text{kV}$$

$$U_{\text{anode}} = -5.4\text{kV, Gn}$$

$$B_{\text{gun}} = 1.5\text{kG}$$

$$B_{\text{main}} = 2\text{kG}$$

$$B_{\text{col}} = 1.5\text{kG}$$

$$F = 200\text{Hz}$$

$$\text{PW} = 4\mu\text{s}$$

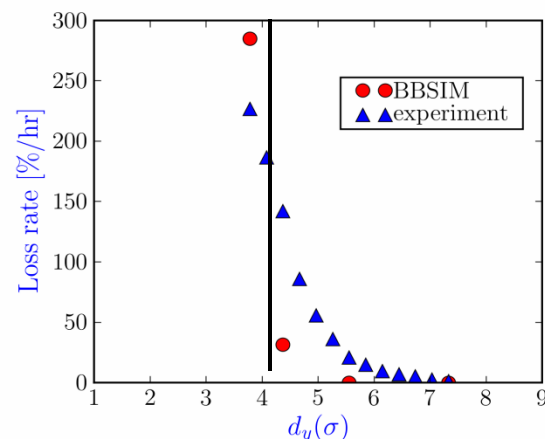




## Accelerator Physics

- Beam-beam simulations and wire compensation [T.Sen]  
FY08: simulations vs experiments in RHIC, benefits to LHC luminosity. Good agreement with single beam.
- Electron Lens compensation [V.Shiltsev] - new in LARP  
FY08: Gaussian e-gun for head-on beam-beam compensation, application to RHIC.
- Crystal Collimation [N.Mokhov] - new  
FY08: Install crystal, measure volume reflection and collimation efficiency

H.J.Kim, T.Sen



## Instrumentation

- Schottky Monitor [A. Jansson]  
FY08: Deliver controls interface to CERN. Monitors installed in LHC.
- AC Dipole [S. Kopp]  
FY08: Linear and nonlinear Tevatron optics measurements. Measured  $\beta^*$  at B0 and D0.
- Chromaticity tracker and feedback [C.Y.Tan]  
FY08: Collaborate with SPS & RHIC measurements



R.Pasquinelli, A.Jansson



- Ground motion in TeV, NuMI (J.Volk *et al*)
  - Crystal Collimation experiment (N.Mokhov, *et al* - with LARP)
  - HTS collaboration (A.Tollestrup *et al* - US wide)
  - Fast cycling HTS conductor test (H.Piekarz *et al* - with CERN)
  - E-cloud studies in MI & CESR (R.Zwaska *et al* - with Project-X team)
  - Space-Charge Compens'n by e-columns (V.Shiltsev *et al*)
  - Optical Diffraction Radiation monitor (T.Sen *et al*)
  - Optical Stochastic Cooling (V.Shiltsev, with MIT, CESR)
  - Dielectric Wall Accelerators-ILA (Yu.Alexahin *et al*)
- support in FY08 limited due to funding issues (but not zero'd)



- Organized by APC :
  - “Project-X Accelerator Physics and Technology” workshop (November 2007)
  - “ILA for Muon Acceleration” workshop (February 2008)
  - APC mini-retreat (March 2008)
  - NFMCC CM (March 2008)
  - “Low-Emittance Muon Collider” workshop (April 2008, with *Muons Inc*)
  - Neutrino Factory IDS meeting (June 2008)





# Fellowships and Programs



## FELLOWSHIP PROGRAM

*John Peoples*

Accelerator Science: Scientific Staff

- R.Zwaska (e-cloud)
- K.Yonehara ( $\mu$ -cooling)
- Y.Sun (emm-exchange)
- L.Prost (AD, e-cooling)
- A.Latina (May'08)

chaired by M.Church



## FELLOWSHIP PROGRAM

*Lee Teng Internship*

Accelerator Physics: Undergraduate Students  
Program Details

- Joint ANL-FNAL-USPAS internship
- Chaired by E.Prebys
- 11 students (5+6) selected for Summer'08
- Will attend USPAS



**Fermilab Internship in Physics of Accelerators and Related  
Technology for International students (PARTI)**

- International students to work in AD/TD/APC/CD
- Chaired by A.Shemyakin
- 8 students this Summer
- Attend lectures, seminars



# US PAS and Accelerator PhD Program



## Current PhD Program Participants

Name	Fermilab Mentor	Institution	Advisor	Project
A. Poklonsky	C. Johnstone/ D. Nueffer	Michigan State	M. Berz	Optimization and control of Tevatron parameters
T. Koeth	H. Edwards	Rutgers University	S. Schnetzer	Sc cavity as a diagnostic for a high-brightness electron beam
A. Paytyan	H. Edwards	Yerevan University	E. Laziev	Control system for superconducting RF cavities
R. Miyamoto	M. Syphers/A. Jansson	University Of Texas/Austin	S. Kopp	New Instrumentation in the Fermilab Tevatron
D. McCarron	P. Spentzouris	IIT	L. Spentzouris	Booster injection beam dynamics
U. Mavric	B. Chase	University of Ljubljana		ILC low level RF
W-M. Tam	G. Romanov/ G. Apollinari	Indiana University	S-Y. Lee	Front End of proposed 8 GeV linac
J. Keung	S. Nagaitsev	University of Pennsylvania	N. Lockyer	NML RF photo injector

## ■ US PAS :

- W. Barletta, Director
- APC hosts the office & provides computer support
- Very successful school in Santa-Rosa (~150 students), next in U. Maryland (~160 enrolled)

## ■ PhD Program:

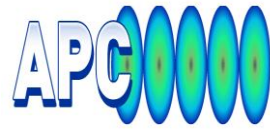
- 8 students enrolled
- 1-2 PhD's yr
- PhD Committee chaired by A. Tollestrup
- Most of the topics - AARD



- It is important to have activities and facilities focused on research beyond near-term accelerator construction plans planned. Main focus:
  1. Acceleration gradients
  2. Beam emittance, beam manipulation and diagnostics
  3. Training of next generation of accelerator physicists
- Fermilab's particular strength is in #2:
  - Expertise in cooling methods (stochastic, electron, ionization)
  - Emittance manipulation (round beams, emm exchange, low  $\varepsilon$ -guns)
  - Novel beam diagnostics (optical bunch length, OTR, ODR, etc)
- Our long-term plans include a bigger facility at NML with few hundred MeV high quality e- beam
- A0 facility (16MeV e-) team is developing intermediate program before the move to NML (ILC, Pr-X, MC, etc)
  - see S.Nagaitsev's talk



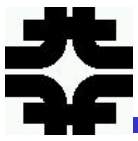
# Conclusions



- APC carries out a broad and successful programme:
  - APC leads commissioning of HINS H- linac in MDB
  - Provides leadership in Muon Collider and Neutrino Factory accelerator research (Lab- and nation-wide)
  - Takes part in operations and studies at FNAL accelerators
  - Leads US-LARP Accelerator Physics work at FNAL
  - Develops new simulation tools and applies them to beam-beam, space-charge, optics design, machine collimation
  - Actively contributes to the Project-X design
- The idea of combining experts in beam theory with accelerator experimentalists in the APC is paying off
- APC coordinates existing and initiates new programs in accelerator education (PFs, PhD program, LTI, PARTI)

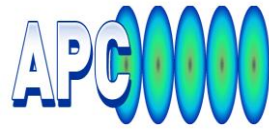
**Overall, the 1<sup>st</sup> year of APC is success!**





# BACKUP SLIDES

---





# APC and Project-X

---



- 325 MHz linac (R.Webber, *et al*):
- Transfer line and stripping (D.Johnson *et al*)
- Beam collimation system (N.Mokhov *et al*)
- Civil construction (D.Bogert *et al*)
- Upgrade specs for Muon Collider PD (C.Ankenbrandt *et al*)
- End-to-end dynamics and space-charge (J.P.Carneiro *et al*)
- Electron cloud simulations and studies (R.Zwaska *et al*)
- Alignment and stabilization (J.Volk *et al*)
- Optics and instabilities (Yu.Alexahin *et al*)

<a href="#">Home</a>
<a href="#">Mission Statement</a>
<a href="#">Organizational Chart</a>
<a href="#">People</a>
<a href="#">Groups</a>
<a href="#">Programs</a>
<a href="#">Education</a>
<a href="#">Meetings and Reviews</a>
<a href="#">Conferences and Workshops</a>
<a href="#">Awards and Honors</a>
<a href="#">Photo Galleries</a>
<a href="#">Contact</a>

## Accelerator Physics Center at Fermilab

The goal of the Accelerator Physics Center is to provide enhanced emphasis on, and support of, accelerator R & D activities aimed at Fermilab's future beyond the end of the current decade. The APC will provide both a physical location and an organizational structure that can accommodate accelerator scientists and engineers, either from Fermilab or outside institutions. The APC will contribute to the improvement of performance of the existing accelerator complex, and the development of new technologies and accelerator concepts that could enable new forefront facilities beyond the current decade.

### News And Events

**February 18, 2008**

Join the Division of Beams of Physics - Special Opportunity ([More Information](#))

**February 18, 2007**

American Physical Society - Member Units - [Division of Physics of Beams](#)

### Education



- [Summer Student Program](#)
- [Lee Teng Internship](#)
- [Accelerator PhD Program](#)
- [USPAS - U.S. Particle Accelerator School](#)
- [Peoples Fellowship](#)

### Groups



High Intensity Neutrino Source (HINS)

[Learn More](#)



ILC Beam Physics

[Learn More](#)



Muon Accelerator R & D

[Learn More](#)



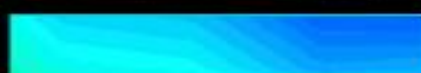
Energy Deposition

[Learn More](#)



LHC Accelerator Group

[Learn More](#)



Theory/Simulation Group

[Learn More](#)



Experimental AAR+D Group

[Learn More](#)

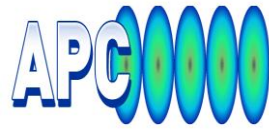


CPA Group

[Learn More](#)



# HINS Program Objectives



- Demonstrate high power RF distribution and long-pulse operation of multiple cavities powered from a single klystron
- Demonstrate 325 MHz high power vector modulators for amplitude and phase control of multiple cavities
- Measure axially-symmetric beam performance with room-temperature crossbar spoke resonator cavities and SC solenoid focusing in the front-end Linac
- Demonstrate high intensity beam acceleration at 10 MeV and beyond using superconducting spoke resonator RF structures
- Demonstrate high-speed (nsec) beam chopping at 2.5 MeV
- Demonstrate performance of this Linac design concept and measure the resulting beam quality to 60 MeV

This all adds up to building a one-of-a-kind SC 60 MeV H- linac





# HINS 2008 Objectives



- Relocate proton ion source from MS6 to MDB and re-commission - May/June
- Begin receiving production SC solenoid magnets and cryostats - July/August
- Receive RFQ from ACCSYS - July
- Commission RFQ to full RF power - September
- Establish 2.5 MeV beam from RFQ - November
- Complete test cryostat fabrication and install cryo transfer lines for HINS test cave - November
- Test first SSR1 SC spoke cavity to full pulsed power - December
- Receive remainder of room temp cavities - December
- Design and begin construction of linac shielding cave in MDB - December



# Tevatron Electron Lenses for BBC



First ever active compensation of beam-beam effects with electron lenses

